

Fuel Cell Forklift Deployment in the U.S.

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Abstract

This chapter provides a brief overview of fuel cell powered material handling equipment (MHE) operated in the United States markets. This chapter first describes current fuel cell technologies used as power source in material handling equipment, then discusses some of the commercially available fuel cell packs and their applications in different MHE classes and finally the chapter concludes with status of fuel cell-powered MHE in 2013 and early 2014. There have been more than 6,286 fuel cell powered forklift installations since 2003, totaling almost 56 MW. These installations include more than 5,881 proton exchange membrane fuel cells and 405 direct methanol fuel cells.

1. Fuel Cell-Powered Material Handling Equipment

Fuel cell systems are a promising technology that can replace batteries in material handling equipment (MHE, or more typically “forklifts”) in warehouse applications where operations usually extend for two or three shifts each day. Battery forklifts generally need to be charged and replaced one or more times each day, which adds complexity to logistics management and increases overall labor costs. Fuel cell forklifts produce zero emissions while in operation and also can operate for more than 12 hours without performance degradation. On the other hand fuel cell MHE can be refueled in couple minutes compared to the charging requirements of batteries which may take several hours. These facts make fuel cells an attractive alternative to conventional battery-powered MHE.

According to Ballard Power Systems (one of the leading PEM fuel cell manufacturers), a typical high throughput warehouse can achieve up to 24 percent savings in total lifetime cost of ownership, which results in a payback period of less than one year, with over 50,000 hours of productivity recovered per year¹. for a typical fleet size of how many forklifts?

Another advantage of fuel cells over other technologies is their wide range of operating temperatures. In fact fuel cells can operate in freezing temperatures, which led Walmart for example, to choose fuel cell lift trucks for its sustainable refrigerated distribution center in Alberta, Canada. The fuel cell-powered forklift can operate in conditions as low as -40° F (-29° C).

Currently, there are two major fuel cell technologies that are used in fuel cell MHE: low temperature proton exchange membrane fuel cells (PEMFC) and direct methanol fuel cells (DMFC). Each technology has its relative advantages and disadvantages such as longer lifetime and high annualized cost of ownership in the case of PEMFC compared to shorter lifetime and

¹ http://www.ballard.com/files/PDF/Material_Handling/Material_Handling_Value_Proposition_4192011.pdf

lower cost of ownership in the case of DMFC. Generally speaking, commercial PEMFC is used in Class I and II forklifts (three- and four-wheel, sit-down, counter-balanced forklifts) used in multi-shift operations, while DMFC is used in class III forklifts (pallet jacks) which typically have less usage in an average working day.

Table 1. Fuel cell technologies for material handling

Material Handling	Technology 1	Technology 2	Reference
Fuel Cell Technology	Proton Exchange Membrane (PEM)	Direct methanol Fuel Cell (DMFC)	
Fuel type	H ₂	Methanol	
Power ranges	1.8-30 kW	1.5kW	
System efficiency	45-59%	<40%	[1-3]
Stack Lifetime	24,000 hr (avg.)	1500 hr (avg.)	[4-5]
Electrical output	27-72V	24V/36V/48V	
Refueling Time	1.5-4 minutes	< 1 min	
Tank capacity	0.72-1.80 kg H ₂	12 liter Methanol	
Weight of the stack (lb)	590-3000	170	
Modeled Cost (\$/kW _{net})	\$3491/kW for 10 kW system @1,000 unit/yr \$2357/kW for 25 kW system @1,000 unit/yr	NA	[6]
Annualized Cost of ownership (\$/lift)	17,800 For class I and II lifts [‡]	11,700 For class III lifts [‡]	[4-5]
Federal Incentive	Credit of 30% of the cost up to \$3,000 per kW	Credit of 30% of the cost up to \$3,000 per kW	[7]

[‡] Class I and II forklifts (three- and four-wheel, sit-down, counter-balanced forklifts) are used in multi-shift operations. Class III: pallet jacks (these have less frequent usage).

Table 2 below summarizes the main fuel cell types used in MHE and some important characteristics like fuel cell type, power output, tank capacity, refueling time, weight and operating temperatures. Figure 1 depicts the numbers of fuel-cell powered MHE units in the past 10 years. It is also worth mentioning that Plug Power, a U.S.-based manufacturer supplies

more than 85% of fuel cell-powered MHE market with the remainder provided by U.S. companies such as Oorja Protonics (DMFC), Nuvera, Hydrogenics and H2Logic (PEMFC) [8].

Table 2. Common forklift fuel cells available in US market

Manufacturer	Product Name	Type	Output	Fuel Storage Capacity	Refueling Time (min)	Wt.	Operating Temperature
H2Logic, Denmark	H2Drive	PEM	~10 kW	1.5 kg H ₂	<4	NA	NA
Hydrogenics, Canada	HyPX Power Packs	PEM / hybrid	22-30kW	0.8 kg H ₂ for HyPX™-2-21 1.6 kg H ₂ for HyPX™-1-27 and HyPX™-1-33 systems	<3	2400-3100 lbs	> 2 to 35 °C (> 36 to 95 °F)
Nuvera Fuel Cells, U.S.	Orion	PEM	10-30 kW	NA	NA	42-75 lbs	-40°C to 60°C (-40°F to 140°F)
Oorja Protonics, U.S.	OorjaPac Model III	DMFC	1.5 kW	12 ltr Methanol	<1	170 lbs	-20 to 45 °C (-4°F to 95°F)
Plug Power [‡] , U.S.	GenDrive Series 1000	PEM	8–10 kW	1.5-1.8 kg H ₂	<3	2,150-3,000 lbs	-30°C to 40°C (-22 to 104°F)
	GenDrive Series 2000	PEM	8–10 kW	1.2 kg H ₂	<2	2300-276 lbs	-30°C to 40°C (-22 to 104°F)
	GenDrive Series 3000	PEM	1.8–3.2 kW	0.72 kg H ₂	<1.5	590 lbs	-30°C to 40°C (-22 to 104°F)

[‡] In 2008, Plug Power made an agreement with Ballard Power Systems to purchase fuel cell stacks for its electric lift truck applications.

Department of Energy (DOE) has recently released 2013 “State of the State” report for fuel cell applications in United States market. This report states that U.S. is still the world leader in fuel cell forklifts, with more than 4,400 units deployed and hundreds more being ordered². Recently,

² Source: <http://www.fuelcells.org/>

Walmart announced that a new deployment of 1,738 GenDrive fuel cell units will occur over the next two years starting from the second quarter of 2014. This hydrogen fuel cell solution will power lift truck fleets at six North America distribution centers. Table 3 below summarizes major projects which took place in 2013 with details about the number of deployed and ordered fuel cell forklifts as well as DOE funded projects that aim to promote fuel cell forklift adoption. Figure 1 also depicts numbers of fuel cell powered MHE in the past 10 years and annual cumulative power in kW. This figure shows a spike in number of deployed forklifts in 2010. This spike was a result of the American Recovery and Reinvestment Act (ARRA) in 2009, a national fiscal stimulus program enacted in response to the financial crisis. Under ARRA, DOE invested \$9.7 million and industry contributed an additional \$11.8 million to support fuel cell deployment in forklift projects [9-10].

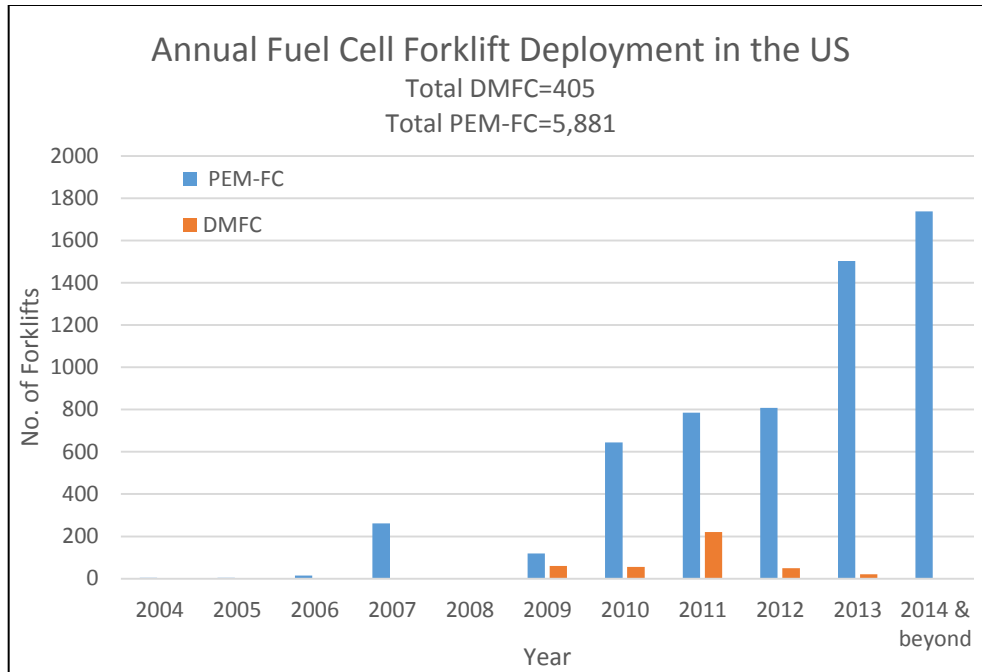
Table 3. Status of fuel cell forklift in 2013 and first quarter of 2014[‡].

State	Project/Location	FC Supplier	Notes
Alabama	Mercedes-Benz U.S. International, Inc.	Plug Power	MBUSI ordered 123 additional fuel cell from Plug Power for its material handling fleet at a new logistics hub in Tuscaloosa. In July 2012, Mercedes purchased 72 fuel cells to operate its Hyster electric truck fleet at its Tuscaloosa vehicle assembly plant. The hydrogen for the fuel cell vehicles is provided by Air Products.
California	UniPro FoodService	Oorja Protonics	Oorja Protonics of Fremont became an approved service provider of its fuel cell systems for UniPro Food Service.
Georgia	Carter's	Plug Power	Children's clothing manufacturer Carter's will add Plug Power fuel cell forklifts to a new site in Georgia.
Louisiana	Associated Wholesale Grocers (AWG)	Plug Power	More than 200 Plug Power fuel cell forklifts have been deployed at AWG Pearl River facility.
Massachusetts/ Texas/California	Thermo King	Nuvera	Nuvera received \$650,000 from DOE to demonstrate Orion™ fuel cell to power transport refrigeration units (TRUs) on tractor trailers used to deliver frozen foods and fresh produce to grocery stores. Nuvera is working with Thermo King to integrate fuel cells in a refrigerated trailer will run for at least 400 hours while supporting two sites, making deliveries for a Sysco food distribution facility in Riverside, California, and for H-E-B's food distribution center in San Antonio, Texas. The Sysco and H-E-B facilities already have fuel cell forklifts in operation with hydrogen infrastructure already in place, provided by Nuvera's PowerTap hydrogen generator and refueling

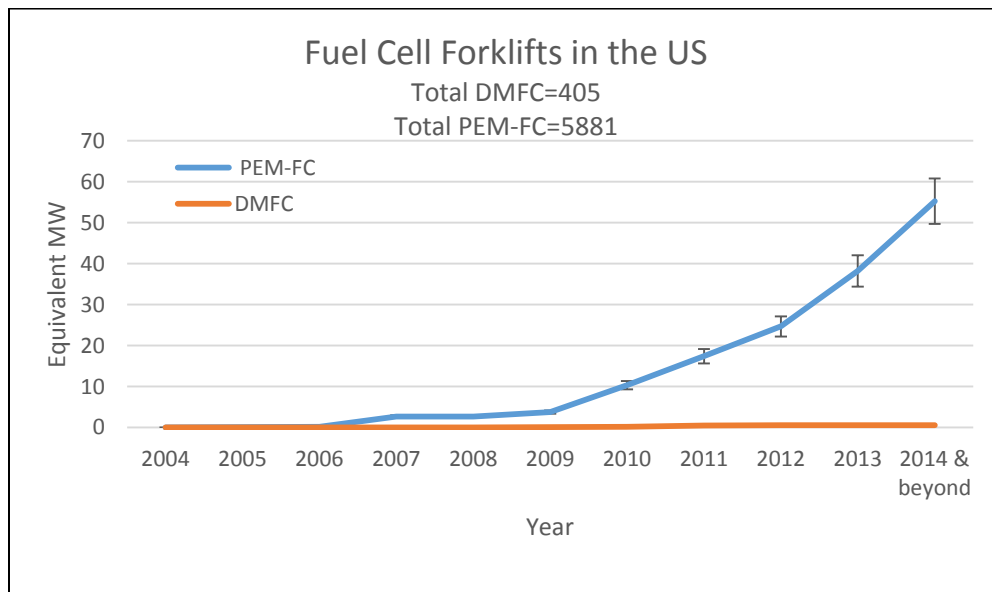
			system.
Missouri	Associated Wholesale Grocers (AWG)	Plug Power	Associated Wholesale Grocers (AWG) has recently deployed 297 Plug Power fuel cell forklifts at its Kansas City facility.
New York	TRU	Plug Power	DOE awarded \$650,000 to Plug Power to demonstrate the use of hydrogen-based fuel cells to power TRUs. Plug Power's TRU fuel cells will cool Carrier Transicold refrigeration units on trailers delivering products for a Sysco Corp. distribution center on Long Island. Each TRU will run for a minimum of 400 hours over the two-year contract period. Hydrogen will be supplied by Air Products.
Pennsylvania	Procter & Gamble Co. (P&G)	Plug Power	Procter & Gamble Co. (P&G) purchased 140 GenDrive® fuel cells from Plug Power for its electric lift truck fleet at its manufacturing facility located in Mehoopany. This expansion in fuel cell installations will increase P&G's fuel cell footprint to four facilities and to more than 340 fuel cell powered forklifts.
South Carolina	BMW Manufacturing Co.	Plug Power	BMW Manufacturing expanded its fleet of fuel cell material handling equipment at its Spartanburg production facility from 100 to 275 units (from Plug Power), which service assembly halls and paint and body shops. Hydrogen for the forklifts is supplied by Linde and stored in a large on-site cylinders. BMW is also planning to use renewable hydrogen from a nearby landfill.
Tennessee	FedEx	Plug Power	Plug Power, has received \$2.5 million from DOE to retrofit 15 electric tow tractors with fuel cells. These retrofitted tractors will be deployed at the FedEx domestic airport in Memphis, Tennessee. Nuvera will provide the hydrogen fueling equipment necessary for this site.
Texas	Ace Hardware	Plug Power	Ace Hardware purchased 65 GenDrive® fuel cell units from Plug Power for its Retail Support Center under construction in Wilmer, Texas.
Several locations	Walmart	Plug Power	Walmart is planning to deploy 1,738 GenDrive fuel cell units over two years starting from the second quarter of 2014. This hydrogen fuel cell solution will power lift truck fleets at six North America distribution centers. Also Walmart and Plug Power have signed an agreement to install GenFuel infrastructure construction and hydrogen fuel supply at these locations and another six-year GenCare service contract for each site ^{††} .

[†] Source of data: Reference [11].

^{††} http://www.plugpower.com/news/pressreleases/14-02-26/plug_power_receives_milestone_order_from_walmart_for_multi-site_hydrogen_fuel_cell_deployment.aspx



(a)



(b)

Figure 1. Fuel Cell Deployment in United States markets in the past 10 years: a) number of deployment by year; and b) cumulative power by year³.

³ Exact system powers for shipped MHE units were not available and cumulative deployed MW reflect authors' best estimates based on system power levels in Table 2. Error bars represent $\pm 10\%$ of author's estimates

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